

(19)



Europäisches Patentamt  
European Patent Office  
Office européen des brevets



(11) Publication number:

**0 269 454 B1**

(12)

## EUROPEAN PATENT SPECIFICATION

- (45) Date of publication of patent specification: **15.04.92** (51) Int. Cl.<sup>5</sup>: **C09J 183/07**  
(21) Application number: **87310474.9**  
(22) Date of filing: **27.11.87**

(54) **Silicone pressure-sensitive adhesive composition.**

(30) Priority: **28.11.86 JP 283343/86**

(43) Date of publication of application:  
**01.06.88 Bulletin 88/22**

(45) Publication of the grant of the patent:  
**15.04.92 Bulletin 92/16**

(84) Designated Contracting States:  
**DE FR GB IT NL SE**

(56) References cited:  
**EP-A- 0 253 601 DE-A- 1 940 124**  
**FR-A- 2 450 642 US-A- 3 983 298**  
**US-A- 4 196 273 US-A- 4 329 273**  
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**EP 0 269 454 B1**

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## Description

The present invention relates to an addition-reacting silicone pressure-sensitive adhesive composition which cures to give a pressure-sensitive adhesive.

5 Silicone pressure-sensitive adhesives have an excellent adhesive strength, tack, and cohesive strength, which are the properties required of a pressure-sensitive adhesive. In addition, they also have the heat resistance, cold resistance, and electrical properties, etc., characteristic of silicones, and so are widely used for electric-insulating tape, which must be very reliable, and for various pressure-sensitive products which must be resistant to hot and cold.

10 In general, organoperoxide-curing compositions (consisting of a mixture of dimethylsiloxane polymer and methylsiloxane resin) are used as silicone pressure-sensitive adhesive compositions. A composition which cures by the addition reaction between alkenyl-containing organopolysiloxane and organopolysiloxane having silicon-bonded hydrogen atoms has also been proposed. Refer to Japanese Patent Publication Number 54-37907 (37,907/79).

15 However, such organoperoxide-curing compositions must be cured by heating at high temperatures, at least 130 degrees Centigrade, in order to convert them into the pressure-sensitive adhesive. As a consequence, they cannot be used with poorly heat-tolerant substrates. At the same time, while the aforementioned addition-curing composition can in fact be cured at lower temperatures than the organoperoxide-curing compositions, the adhesive strength of the former is inferior to that of the latter.

20 The inventors carried out investigations in order to eliminate these problems residing in the prior art, and the present invention was developed as a consequence.

The object of the present invention is to provide a pressure-sensitive adhesive composition which can be cured at relatively low temperatures into a pressure-sensitive adhesive having an excellent tack and cohesive strength and a high adhesive strength in particular. This object, and others which will become  
25 apparent upon consideration of this disclosure and appended claims, are obtained by the present invention which, in brief, is a composition having specified quantities of a lower alkenyl group-terminated polydiorganosiloxane, an organopolysiloxane composed of  $R^2_3SiO_{1/2}$  units and  $SiO_2$  units and containing no more than 1 weight percent hydroxyl groups, an organopolysiloxane having at least 2 silicon-bonded hydrogen atoms in each molecule, and a platinum-containing catalyst. It characteristically can be cured at relatively  
30 low temperatures into a pressure-sensitive adhesive having an excellent tack and cohesive strength, and particularly a high adhesive strength.

The present invention relates to a silicone pressure-sensitive adhesive composition comprising (A) 30 to 70 weight parts of a polydiorganosiloxane having the general formula  $R^1R_2SiO(R_2SiO)_nSiR_2R^1$  wherein each R is a monovalent hydrocarbon group, each  $R^1$  is a lower alkenyl group and n is an integer, (B) 70 to 30  
35 weight parts of an organopolysiloxane which is constituted of  $R^2_3SiO_{1/2}$  units and  $SiO_2$  units in a molar ratio in the range of 0.6:1 to 0.9:1, wherein  $R^2$  is selected from among alkyl groups, alkenyl groups, and the hydroxyl group, and the methyl group comprises at least 95 mol percent of all  $R^2$  groups and which has a silicon-bonded hydroxyl content of no more than 1 weight percent, (C) an organohydrogenpolysiloxane having an average of at least 2 silicon-bonded hydrogen atoms in each molecule, in a quantity sufficient to  
40 provide from 1 to 40 silicon-bonded hydrogen atoms per alkenyl group in component (A), and (D) a platinum-containing catalyst in a quantity sufficient to provide 0.1 to 1,000 weight parts platinum for each one million weight parts of the combined quantity of components (A) through (C).

To explain the preceding, component (A) is the principal component of the pressure-sensitive adhesive composition of the present invention, and curing proceeds by its addition-reaction with component (C) under  
45 the catalytic activity of component (D).

Component (A) is a polydiorganosiloxane having the general formula  $R^1R_2SiO(R_2SiO)_nSiR_2R^1$  which must have an alkenyl group, which is essential to the addition reaction, at both of its molecular terminals. R in the above formula can be any monovalent hydrocarbon group, for example, alkyl groups such as methyl, ethyl, propyl, etc.; alkenyl groups such as vinyl, allyl, propenyl, etc.; and aryl groups such as the phenyl  
50 group, etc. R preferably contains from 1 to 6 carbon atoms and methyl is in general a preferred R radical. Particularly when heat resistance is required, the phenyl group and methyl group will be present together.  $R^1$  is to be an alkenyl group such as vinyl, allyl, propenyl, etc., and a lower alkenyl group such as vinyl is preferred.

No specific restriction obtains on the molecular weight of component (A), or on the value of n in the above formula, as long as no adverse effect accrues with respect to the workability of the pressure-sensitive adhesive composition of the present invention in practical applications. In concrete terms, a solventless pressure-sensitive adhesive composition can be prepared when n is an integer such that the viscosity of  
55 component (A) is no more than 100,000 centipoise. To prepare a solvent-containing (organic solvent)

pressure-sensitive adhesive composition, in terms of the value of  $n$  and the molecular weight of component (A), the use is preferred of a polydiorganosiloxane having a viscosity of at least one million centipoise, a so-called silicone gum. When the viscosity of component (A) is greater than 100,000 centipoise but less than 1 million centipoise, a suitable quantity of organic solvent, as will be discussed below, is added.

5 Alkenyl-terminated polydiorganosiloxanes are well known in the organosilicone art and their syntheses need no further delineation herein. Typically, an alkenyl-containing terminating reactant, such as divinyl-tetramethyldisiloxane, is equilibrated with a diorganosiloxane reactant, such as octamethylcyclotetrasiloxane, in the presence of an acidic or alkaline catalyst. A phenyl group-containing and/or a vinyl group-containing diorganosiloxane reactant can also be included in the reaction mixture to introduce phenyl and/or vinyl  
10 groups into the polymer chain, if desired. Additionally, phenyl groups can be incorporated into the alkenyl group-containing terminating reactant, if desired. The molecular weight of the polydiorganosiloxane can be controlled by use of the appropriate amount of terminating reactant, in the well-known manner.

Component (B) is an organopolysiloxane which is constituted of  $R^2_3SiO_{1/2}$  units and  $SiO_2$  units and is the component which imparts adhesive strength to the cured pressure-sensitive adhesive. In the above  
15 formula,  $R^2$  is selected from among alkyl groups such as methyl, ethyl, and propyl, etc.; alkenyl groups such as vinyl and allyl, etc.; and the hydroxyl group; and at least 95 mol percent of all groups  $R^2$  are to be methyl. Furthermore, in the present invention, the total  $R^2$  group complement is to contain no more than 0.5 mol percent, and preferably contains 0 mol percent, alkenyl groups.

The molar ratio of  $R^2_3SiO_{1/2}$  units to  $SiO_2$  units must fall within the range of 0.6:1 to 0.9:1. The tackiness  
20 is reduced at below 0.6  $R^2_3SiO_{1/2}$  units per  $SiO_2$  unit, while the cohesive strength is reduced at above 0.9  $R^2_3SiO_{1/2}$  units per  $SiO_2$  unit. Methods for synthesizing and analyzing such organopolysiloxanes are known. Refer to U.S. Patent No. 2,676,182, which is incorporated herein by reference.

Component (B) is to contain no more than 1 weight percent silicon-bonded hydroxyl groups based on the total weight of component (B), and preferably contains no more than 0.6 weight percent. A high  
25 adhesive strength cannot be obtained when this content of silicon-bonded hydroxyl groups exceeds 1 weight percent. This hydroxyl group content is particularly important in the present invention. The composition of the invention is a multicomponent composition in which component (B) is defined as having in addition to a particular molar ratio of  $SiO_{1/2}$  and  $SiO_2$  units a requirement that the silicon-bonded hydroxyl content should be no more than one weight percent. Not only is such a requirement absent from US-A-  
30 3983298 but a review of the disclosure of that document shows that mentions of the weight percentage of silicon-bonded hydroxyl units are exemplified above the present upper limit. It is referred for example, to the showing of 3-4% by weight of silicon-bonded hydroxyl radicals at column 4, lines 6 and 7 of US-A-3983298 and also to Table III in which the lowest weight percentage of hydroxyl is 1.53.

The quantities of components (A) and (B) that are present in the compositions of this invention can  
35 range, independently, from 30 to 70 parts by weight each. Thus the weight ratio of component (A) to component (B) can range from about 0.43 to about 2.33. The quantities of components (C) and (D) that are present in the compositions of this invention are dependent upon the quantities of component (A) and components (A) + (B) + (C), respectively, as noted below.

Component (C) is an organohydrogenpolysiloxane having an average of at least 2 silicon-bonded  
40 hydrogen atoms in each molecule and functions as a crosslinker for component (A). Curing proceeds by the addition reaction of the silicon-bonded hydrogen atoms in this component with the alkenyl groups in component (A) under the catalytic activity of component (D).

Component (C) can be any of the currently known organohydrogenpolysiloxanes, particularly methyl-hydrogenpolysiloxanes, having an average of at least two, and preferably three or more, silicon-bonded  
45 hydrogen atoms per silicon atom. The molecular structure of this component is not critical and can be cyclic, linear, branched and/or network, as desired. The organic groups in Component (C) can be any monovalent hydrocarbon group free of aliphatic unsaturation, as is well known, such as the general and specific alkyl and aryl groups denoted above for Component (A). For maximum compatibility of Components (A), (B) and (C) the organic groups in each component are preferably the same.

50 The quantity of component (C) is to be sufficient to provide 1 to 40 silicon-bonded hydrogen atoms per alkenyl group in component (A); a satisfactory cohesive strength cannot be generated when either 40 is exceeded or when less than 1 is present.

Component (D) is a platinum-containing catalyst, and it promotes the addition reaction of component (A) with component (C). Concrete examples here are chloroplatinic acid, chloroplatinic acid-olefin complexes,  
55 chloroplatinic acid-vinylsiloxane complexes, and platinum supported on a microparticulate carrier such as alumina.

Component (D) is added in a quantity sufficient to give 0.1 to 1,000 weight parts platinum and preferably 1 to 300 weight parts platinum for each one million weight parts of the combined quantity of

components (A) through (C). The crosslinking reaction will be unsatisfactory at below 0.1 weight part, and the cohesive strength will thus be reduced, while exceeding 1,000 weight parts is disadvantageous due to the resulting short use time and high cost.

In addition to components (A) to (D), an appropriate quantity of an organic solvent can be used in the present invention to dissolve components (A) through (D) and provide for ease of application of the pressure-sensitive adhesive composition of the present invention to various substrates. Concrete examples of this component are hydrocarbons, such as toluene, xylene, and mineral spirits; halohydrocarbons, alcohols, esters, ketones and combinations of these solvents.

In addition to components (A) through (D), any of the addition-reaction inhibitors known in the art may be added in the present invention. Concrete examples thereof are 3-methyl-3-pentene-1-yne, 3,5-dimethyl-3-hexene-1-yne and acetylenic alcohols, for example, 3-methyl-1-butyne-3-ol, 3,5-dimethyl-1-hexyne-3-ol, 3-methyl-1-pentyne-3-ol, and phenylbutynol.

Furthermore, the addition of small quantities of supplementary components to the composition of the present invention is permissible. Such supplementary components are, for example, the various antioxidants, pigments, stabilizers, and fillers.

With regard to the substrate in pressure-sensitive products which may be obtained using the pressure-sensitive adhesive composition of the present invention, various materials are useable here, for example, plastic films such as films of polyester, polyolefin, such as polytetrafluoroethylene, or polyimide; paper such as Japanese paper and synthetic paper; textiles; glass wool; and metal foils.

The present invention will be explained in the following using illustrative examples. In the examples, parts = weight parts, and % = weight percent. The properties reported in the examples were measured by the following methods.

#### Measurement of adhesive strength.

The silicone pressure-sensitive adhesive composition was coated in the specified thickness on the substrate, followed by thermal curing. The resulting pressure-sensitive tape was pressed using a 2 kg rubber roller onto stainless steel plate (SUS304) whose surface had been polished in advance with number 280 water-resistant polishing paper. After standing for 1 hour at room temperature, the tape was peeled using a tensile tester (Tensilon from Toyo-Baldwin Kabushiki Kaisha) at a rate of 0.3 m/minute in order to measure the adhesive strength, which is expressed in units of g/2.5 cm.

#### Measurement of cohesive strength.

Pressure-sensitive tape produced as in the aforementioned measurement of adhesive strength was pressed over an area corresponding to a length of 20 mm and a width of 10 mm using a 2 kg rubber roller onto stainless steel plate (SUS304) whose surface had been polished in advance with number 280 water-resistant polishing paper. A 500 g load was applied to the lower end of the pressure-sensitive tape, and this was suspended in an oven at 100 degrees Centigrade for 2 hours. The slippage was measured using a viewing microscope, and is expressed in mm.

#### Measurement of the ball tack.

Pressure-sensitive tape produced as in the measurement of adhesive strength was placed with the tack surface up on a ball tack tester (Tester Sangyo Kabushiki Kaisha) inclined at an angle of 30 degrees. Steel balls of various sizes were rolled down from a 10 cm long runway. The reported value is the diameter, in units of 1/32 inch, of the largest steel ball which came to a halt on a tack surface 10 cm in length.

For example, a reported value of 10 means that a steel ball with a diameter of 10/32 inch was the largest steel ball coming to rest on the tack surface. This measurement was conducted at room temperature.

#### Example 1

55 Parts methylpolysiloxane composed of  $(\text{CH}_3)_3\text{SiO}_{1/2}$  units and  $\text{SiO}_2$  units in a 0.7 : 1 molar ratio and having a hydroxyl group-content of 0.5%, 45 parts dimethylvinylsiloxy-terminated polydimethylsiloxane gum having a vinyl group content of 0.02%, 0.2 parts trimethylsiloxy-terminated methylhydrogenpolysiloxane having a viscosity of 20 centipoise and containing 1.6% silicon-bonded hydrogen atoms, and 0.2 parts 3-methyl-1-butyne-3-ol reaction inhibitor were dissolved in 150 parts toluene. The molar ratio of silicon-

bonded hydrogen atoms to vinyl groups was 9.6:1 in this mixture. A pressure-sensitive adhesive composition (40% nonvolatiles) was obtained by adding chloroplatinic acid-vinylsiloxane complex to this mixture in an amount sufficient to give 100 ppm platinum based on the combined quantity of the above polysiloxanes.

This composition was coated on 50 micron-thick aluminum foil and heated at 80 degrees Centigrade for 5 minutes to give a 50 micron-thick film after heating. The film-forming performance, adhesive strength, ball tack, and cohesive strength of the obtained aluminum foil-backed pressure-sensitive tape were measured, and these results are reported in Table 1.

For comparison, a pressure-sensitive adhesive composition was produced as above, but using a methylpolysiloxane containing 2.0% hydroxyl groups in place of the above methylpolysiloxane containing 0.5% hydroxyl groups. This composition was evaluated by the same methods, and these results are also reported in Table 1.

According to Table 1, the pressure-sensitive adhesive composition of the present invention was found to have an adhesive strength superior to that of the comparison example.

Table 1

Item Measured	Present Invention	Comparison Example
Adhesive Strength	4,300 g/2.5 cm	3,500 g/2.5 cm
Ball Tack	24	24
Cohesive Strength	0 mm	2.0 mm

### Example 2

50 Parts methylpolysiloxane which is composed of  $(\text{CH}_3)_3\text{SiO}_{1/2}$  units and  $\text{SiO}_2$  units in a 0.7:1 molar ratio and which contains 0.5% hydroxyl groups, 50 parts dimethylvinylsiloxy-terminated polydimethylsiloxane having a viscosity of 40,000 centipoise, 0.4 parts trimethylsiloxy-terminated dimethylsiloxane-methylhydrogensiloxane copolymer having a viscosity of 10 centipoise (silicon-bonded hydrogen atom: silicon-bonded methyl group molar ratio = 1:3), and 0.2 parts 3,5-dimethyl-3-hexene-1-yne were mixed. The molar ratio of silicon-bonded hydrogen atoms to vinyl groups was 2.2:1 in this mixture. A solventless pressure-sensitive adhesive composition was obtained by adding chloroplatinic acid-vinylsiloxane complex to this mixture in an amount sufficient to give 100 ppm platinum based on the combined quantity of the polysiloxanes. This was coated to give a thickness of 50 microns on 50 micron aluminum foil, and was then cured at 100 degrees Centigrade for 3 minutes. The properties of the obtained aluminum-backed pressure-sensitive tape were evaluated, and these results are reported in Table 2.

For comparison, a pressure-sensitive adhesive composition was prepared from the same components as above, with the exception that methylpolysiloxane containing 1.8% hydroxyl groups was used in place of the methylpolysiloxane containing 0.5% hydroxyl groups. This composition was evaluated by the same methods as above, and these results are also reported in Table 2.

Table 2

Item Measured	Present Invention	Comparison Example
Adhesive Strength	3,500 g/2.5 cm	3,000 g/2.5 cm
Ball Tack	30	30
Cohesive Strength	0.20 mm	0.20 mm

### Example 3

The pressure-sensitive adhesive composition of Example 1 was prepared except that 0.4 parts of the same methylhydrogen polysiloxane was employed wherein the molar ratio of silicon-bonded hydrogen atoms to vinyl groups was 19.2:1. This composition was evaluated by the same methods as above and the results are reported in Table 3.

#### Example 4

The pressure-sensitive adhesive composition of Example 1 was prepared except that 1.2 parts of trimethylsiloxy-terminated dimethylsiloxane-methylhydrogensiloxane copolymer was employed instead of the 0.2 parts of methylhydrogenpolysiloxane, wherein the molar ratio of silicon-bonded hydrogen atoms to vinyl groups was 28.8:1. This composition was evaluated by the same methods as above and the results are reported in Table 3.

Table 3

Item Measured	Example 3	Example 4
Adhesive Strength	4,300 g/2.5 cm	3,500 g/2.5 cm
Ball Tack	24	32
Cohesive Strength	0 mm	0.8 mm

#### EFFECTS OF THE INVENTION

Because the silicone pressure-sensitive adhesive composition of the present invention is composed of specified quantities of (A) lower alkenyl group-terminated polydiorganosiloxane, (B) organopolysiloxane composed of  $R^2_3SiO_{1/2}$  units and  $SiO_2$  units and containing no more than 1 weight percent hydroxyl groups, (C) organopolysiloxane having at least 2 silicon-bonded hydrogen atoms in each molecule, and (D) a platinum-containing catalyst, it characteristically can be cured at relatively low temperatures into a pressure-sensitive adhesive having an excellent tack and cohesive strength, and particularly a high adhesive strength.

#### Claims

1. A silicone pressure-sensitive adhesive composition comprising
  - (A) 30 to 70 weight parts of a polydiorganosiloxane having the general formula  $R^1R_2SiO(R_2SiO)_nSiR_2R^1$  wherein each R is a monovalent hydrocarbon group, each  $R^1$  is a lower alkenyl group and n is an integer,
  - (B) 70 to 30 weight parts of an organopolysiloxane which is constituted of  $R^2_3SiO_{1/2}$  units and  $SiO_2$  units in a molar ratio in the range of 0.6:1 to 0.9:1, wherein  $R^2$  is selected from among alkyl groups, alkenyl groups, and the hydroxyl group, and the methyl group comprises at least 95 mol percent of all  $R^2$  groups and which has a silicon-bonded hydroxyl content of no more than 1 weight percent,
  - (C) an organohydrogenpolysiloxane having an average of at least 2 silicon-bonded hydrogen atoms in each molecule, in a quantity sufficient to provide from 1 to 40 silicon-bonded hydrogen atoms per alkenyl group in component (A), and
  - (D) a platinum-containing catalyst in a quantity sufficient to provide 0.1 to 1,000 weight parts platinum for each one million weight parts of the combined quantity of components (A) through (C).
2. A silicone pressure-sensitive adhesive composition in accordance with claim 1 further comprising at least one addition-reaction inhibitor.
3. A silicone pressure-sensitive adhesive composition in accordance with claim 1 further comprising at least one solvent for components (A) through (D).

#### Revendications

1. Composition adhésive à base de silicone sensible à la pression, comprenant
  - (A) 30 à 70 parties en poids d'un polydiorganosiloxane de formule générale  $R^1R_2SiO(R_2SiO)_nSiR_2R^1$ , dans laquelle chaque R est un groupe hydrocarboné monovalent, chaque  $R^1$  est un groupe alkényle inférieur et n est un nombre entier,
  - (B) 70 à 30 parties en poids d'un organopolysiloxane constitué d'unités  $R^2_3SiO_{1/2}$  et d'unités  $SiO_2$  dans un rapport molaire de 0,6 : 1 à 0,9 : 1, dans lequel  $R^2$  est choisi parmi les groupes alkyles, les groupes alkényles et le groupe hydroxyle, et le groupe méthyle forme au moins 95 moles pour cent de tous les groupes  $R^2$ , et qui a une teneur en groupes hydroxyle liés au silicium ne dépassant pas

1% en poids.

(C) un organohydrogénopolysiloxane ayant une moyenne d'au moins 2 atomes d'hydrogène liés au silicium dans chaque molécule, en une quantité suffisante pour fournir de 1 à 40 atomes d'hydrogène liés au silicium par groupe alkényle dans le constituant (A), et

5 (D) un catalyseur contenant du platine en une quantité suffisante pour fournir de 0,1 à 1.000 parties en poids de platine pour chaque million de parties en poids de la quantité combinée des constituants (A) à (C).

2. Composition adhésive à base de silicone sensible à la pression suivant la revendication 1, comprenant  
10 en outre au moins un inhibiteur de réaction d'addition.

3. Composition adhésive à base de silicone sensible à la pression suivant la revendication 1, comprenant en outre au moins un solvant pour les constituants (A) à (D).

# 15 Patentansprüche

1. Siliconhaftkleberzusammensetzung, enthaltend

(A) 30-70 Gewichtsteile eines Polydiorganosiloxans der allgemeine Formel  $R^1R_2SiO(R_2SiO)_nSiR_2R^1$ , in der jedes R eine einwertige Kohlenwasserstoffgruppe ist, jedes  $R^1$  eine niedere Alkenylgruppe ist  
20 und n eine ganze Zahl ist,

(B) 70-30 Gewichtsteile eines Organopolysiloxans, das aus  $R^2_3SiO_{1/2}$ -Einheiten und  $SiO_2$ -Einheiten aufgebaut ist in einem Molverhältnis im Bereich von 0,6:1 bis 0,9:1, wobei  $R^2$  ausgewählt ist aus Alkylgruppen, Alkenylgruppen und der Hydroxylgruppe und die Methylgruppe mindestens 95 Mol-% aller  $R^2$ -Gruppen ausmacht, und das einen Gehalt von an Silizium gebundenen Hydroxylgruppen von  
25 nicht mehr als 1 Gew.-% aufweist,

(C) ein Organohydrogenopolysiloxan mit im Mittel mindestens 2 an Silizium gebundenen Wasserstoffatomen in jedem Molekül, in einer ausreichenden Menge, um 1-40 an Silizium gebundene Wasserstoffatome pro Alkenylgruppe von Bestandteil (A) zu schaffen, und

(D) einen platinhaltigen Katalysator in einer ausreichenden Menge, um 0,1-1.000 Gewichtsteile Platin pro eine Million Gewichtsteile der kombinierten Menge der Bestandteile (A) bis (C) zu ergeben.  
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2. Siliconhaftkleberzusammensetzung nach Anspruch 1, **dadurch gekennzeichnet**, daß sie weiterhin mindestens einen Inhibitor für Additionsreaktion enthält.

35 3. Siliconhaftkleberzusammensetzung nach Anspruch 1, **dadurch gekennzeichnet**, daß sie weiterhin mindestens ein Lösemittel für die Bestandteile (A) bis (D) enthält.

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